



UNITED STATES DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY
WATER RESOURCES DIVISION

Prepared in cooperation with the
IDAHO DEPARTMENT OF RECLAMATION

Boise, Idaho

1970

UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY
Water Resources Division

THE RAFT RIVER BASIN, IDAHO-UTAH, AS OF 1966: A REAPPRAISAL
OF THE WATER RESOURCES AND EFFECTS OF GROUND-WATER DEVELOPMENT

By

E. H. Walker, L. C. Dutcher, S. O. Decker, and K. L. Dyer

Prepared in cooperation with the
Idaho Department of Reclamation

OPEN-FILE REPORT

Boise, Idaho
April 1970

ERRATA

- p. 20, Table 1. Two "Normal precipitation" values were inadvertently omitted from this table. They are: all.00 for Standrod and all.02 for Snowville.
- p. 47. Precipitation values for August were inadvertently omitted from the tabulation shown on this page. The missing values are: Malta-Minidoka - .55; Factor - 1.05; Selected site - .59.
- p. 111. The last line on this page should read "several hundred feet, to effect major salvage."

CONTENTS

	Page
Abstract-----	1
Introduction-----	4
Conclusions-----	6
Previous work and reports-----	11
Purpose and scope-----	13
Reference period used in the report-----	14
Acknowledgments-----	14
The environment-----	15
Geographic features-----	15
Mountain ranges-----	16
Principal valleys and subbasins-----	17
Climate-----	19
Precipitation-----	19
Temperature and evaporation-----	24
Irrigated area and remaining unirrigated land-----	28
The geologic framework-----	29
General distribution and stratigraphy of the rocks	29
Rocks of pre-Tertiary age-----	30
Salt Lake Formation-----	32
Raft Formation-----	33
Basalt of the Snake River Group-----	34
Alluvium, fan deposits, landslides, and glacial deposits-----	34
Structure-----	35
The aquifer system-----	37
Lateral boundaries-----	37
Raft River valley subbasin-----	38
Yost-Almo subbasin-----	39
Elba subbasin-----	39
Thickness and extent of the water-bearing rocks-----	39
Water yield of the basin-----	42
Previous estimates-----	44
Present estimate-----	45
The hydrologic system-----	60
Surface-water inflow and outflow-----	60
Runoff-----	61
Mean annual inflow-----	63
Surface-water diversion and use-----	70
Outflow from Raft River valley subbasin-----	71

CONTENTS

	Page
The hydrologic system--Continued	
Ground water-----	72
Occurrence of ground water-----	73
Depth to ground water-----	73
Ground-water recharge-----	74
Ground-water movement-----	75
Yost-Almo subbasin-----	76
Elba subbasin-----	77
Raft River valley subbasin-----	78
Ground-water discharge-----	79
Wells and well yields-----	79
Water-level changes-----	82
Ground-water pumping-----	85
Consumptive use of ground water-----	88
The water budget-----	91
Ground water in storage-----	94
Specific yield-----	95
Change in storage-----	97
Chemical quality of water-----	100
Surface water-----	100
Direct runoff-----	102
Base flow-----	102
Ground water-----	105
Quality conditions within subbasins-----	106
Change in salt balance-----	108
Perennial yield of the basin-----	109
Basic concepts-----	109
Salvaging ground-water outflow-----	111
References cited-----	114

ILLUSTRATIONS

Figure		Page
1.	Map of the Raft River basin, Idaho and Utah-----	pocket
2.	Isohyetal map of the Raft River basin, Idaho and Utah-----	pocket
3.	Approximate relation between altitude and precipitation-----	23
4.	Generalized seasonal precipitation distribution for different parts of the Raft River basin-----	25

ILLUSTRATIONS

	Page
Figure 5. Map showing approximate extent of irrigated land in 1966-----	pocket
6. Correlation of chronologic, stratigraphic, and hydrologic units in Raft River basin--	31
7. Geologic cross sections, Raft River basin---	pocket
8. Approximate thickness of water-bearing units	pocket
9. Comparison between streamflow and precipitation-----	43
10. Empirical curves for computation of average monthly precipitation at ungaged sites----	48
11. Log probability of annual precipitation at Oakley and Idaho City-----	56
12. Annual precipitation in excess of average at a selected site and computed long-term annual water yield-----	57
13. Map showing distribution of water yield-----	pocket
14. Map showing wells and water-level contours--	pocket
15. Hydrographs of selected wells in southern part and runoff of Clear Creek near Naf---	81
16. Hydrographs of selected wells in the central part, annual ground-water pumpage, and runoff of Raft River at Peterson Ranch, near Bridge-----	84
17. Hydrographs of selected wells in the northern part-----	86
18. Ground water pumped and number of irrigation wells-----	89
19. Map showing estimated average specific yield of water-bearing deposits -----	96
20. Map showing net water-level change, spring 1952 to spring 1966-----	98
21. Distribution of water yield, water use, change in storage, and projected water-resources distribution-----	101
22. Map showing diagrammatically chemical quality of water in streams-----	pocket
23. Map showing chemical quality of ground water	pocket

TABLES

	Page
Table 1. Average monthly and annual precipitation in Raft River basin and adjacent areas-----	20
2. Precipitation records from storage gages-----	22
3. Mean monthly and annual temperature in Raft River basin and adjoining areas-----	26
4. Evaporation from class A land pan at Minidoka Dam-----	27
5. Average monthly and yearly potential evapo-transpiration at selected altitudes-----	52
6. Estimated average annual water yield-----	58
7. Yearly runoff, in acre-feet, at gaging stations-----	64
8. Monthly and yearly streamflow at partial-record sites-----	65
9. Surface runoff and related data at gaged sites, adjusted to 1931-60 average-----	66
10. Ground water pumped, in acre-feet, 1948-66---	87
11. Estimated irrigated acreage, pumpage, consumptive use, and outflow of both ground water and surface water, 1928-66-----	92

THE RAFT RIVER BASIN, IDAHO-UTAH, AS OF 1966: A REAPPRAISAL
OF THE WATER RESOURCES AND EFFECTS OF GROUND-WATER DEVELOPMENT

By E. H. Walker, L. C. Dutcher, S. O. Decker, and K. L. Dyer

ABSTRACT

The Raft River basin, mostly in south-central Idaho and partly in Utah, is a drainage basin of approximately 1,510 square miles. Much arable land in the basin lacks water for irrigation, and the potentially irrigable acreage far exceeds the amount that could be irrigated with the 140,000 acre-feet estimated annual water yield. Therefore, the amount of uncommitted water that could be intercepted and used within the basin is the limiting factor in further development of agriculture irrigated with water derived from within the basin. Water for additional irrigation might be obtained by pumping more ground water, but only if large additional ground-water storage depletion can be tolerated. Alternatively, supplemental water might be imported.

The Raft River basin is an area of rugged mountain ranges, aggraded alluvial plains, and intermontane valleys. Topography and geologic structure strongly influence the climate and hydrology. The Raft River rises in the Goose Creek Range of northwestern Utah and flows generally northeastward and northward, joining the Snake River in the backwater of Lake Walcott.

The climate ranges from cool subhumid in the mountains to semiarid on the floor of the Raft River valley. Precipitation ranges from less than 10 inches on the valley floor to more than 30 inches at some places in the mountains. Rainfall is light during the growing season of about 100 days, and irrigation is necessary for most cultivated crops.

About 87,000 acres of land was irrigated in the 1960's, on the average, and most of that is in the lower Raft River valley. Nearly all usable surface water in the basin is diverted for irrigation and as of 1966 less than 20,000 acres was irrigated exclusively with surface water. Most stock, farm, and domestic water is from wells. Irrigation with ground water is widely practiced and about 69,000 acres was irrigated partly or wholly with ground water in 1966. In 1963 the valley was closed to further issuance of permits to appropriate ground-water because of declining water levels.

Geologic structure, lithology, and physiographic history control the surface-drainage pattern as well as the occurrence and movement of ground water. The principal water-bearing formations are the Salt Lake Formation of Pliocene age, consisting mainly of weakly consolidated sandy sediments and some layers of volcanic rock; the Raft Formation of Pleistocene age consisting of sand and gravel, lake sediments, and thin beds of silt and clay; and alluvial deposits of Holocene age that form aquifers beneath the bottom lands of the valleys. Good yields from wells, ranging upward to several thousand gallons a minute, are obtained from the water-bearing formations. Basalt lavas of the Snake River Group yield water where they occur below the water table of the valley. A few wells that penetrate limestone obtain substantial supplies from crevices.

Thickness of the composite aquifer ranges from 0 to more than 1,500 feet. Transmissivity of the composite aquifer is estimated to vary from about 10,000 gpd/ft (gallons per day per foot) along the basin margins to more than 450,000 gpd/ft. Permeability of the water-bearing deposits is highly variable, but is estimated to average about 300 gpd/ft² for the basin as a whole.

The ground-water storage capacity of the basin is large; in the lower Raft River subbasin alone, the upper 200 feet of saturated deposits contain an estimated 9,000,000 acre-feet of water. The average specific yield of the shallow deposits is estimated to be 20 percent.

The water yield of the Raft River basin is estimated to average about 140,000 acre-feet per year as compared to 183,600 acre-feet estimated by Nace and others (1961) and 320,000 acre-feet estimated by Mundorff and Sisco (1963). Surface outflow of the Raft River to the Snake River now amounts to only about 1,900 acre-feet per year, a decline of about 15,000 acre-feet a year from the estimated original average outflow prior to irrigation of about 17,000 acre-feet per year.

Ground-water outflow from the basin originally averaged approximately 83,000 acre-feet annually; it has declined only slightly as a result of pumping and was estimated to be about 80,000 acre-feet annually in 1966.

In general, the quality of surface and ground water is good; dissolved solids in a few exceptional wells range up to more than 2,000 mg/l (milligrams per liter) where the temperature is high or where a substantial percentage of water pumped was previously used for irrigation. Most of the surface and ground water is suitable for irrigation and has a dissolved solids content of less than 600 mg/l, mainly calcium bicarbonate. Dissolved-solids concentration in the surface-water outflow from the basin is increasing.

The pumping of ground water has caused a net water-level decline beneath about 235 square miles of the valley floor. Beneath and adjacent to the bottom lands, water levels recover a number of feet during years of above-average runoff, owing to recharge from the Raft River and Cassia Creek. However, a steady decline of as much as 5 feet per year is occurring beneath pumped areas that are some distance from sources of recharge.

Consumption of ground water for irrigation, under present-day practices, averages about 1.6 feet per acre annually. Total consumption of water by irrigated crops has risen from about 40,000 acre-feet to about 160,000 acre-feet annually.

Pumping of ground water increased from approximately 8,600 acre-feet in 1948 to 235,000 acre-feet in 1966, a year of deficient streamflow.

Assuming 20 percent for the specific yield of the water-bearing formations, the depletion of ground-water storage during the 14 years 1952 to 1965 inclusive was approximately 410,000 acre-feet. By the end of 1966 it was nearly 515,000 acre-feet.

Salvage of ground-water outflow from Raft River valley subbasin will require reduction or elimination of the present northward hydraulic gradient of about 15 feet per mile. Reducing the gradient by one half would salvage about one half the outflow, or about 40,000 acre-feet annually. However, with present pumping patterns and quantities, this reduction would require several hundred feet of water-level decline near the pumping wells, many decades of time, and several millions of acre-feet of additional depletion of stored ground water.

INTRODUCTION

The Raft River basin, mostly in south-central Idaho but partly in northern Utah, is a major drainage basin tributary to the Snake River. Prior to development and use of its water resources by man, the basin contributed an estimated average 100,000 acre-feet of surface and subsurface flow to the Snake River system annually. Of the remaining estimated 140,000 acre-feet total annual water yield, about 40,000 acre-feet was nonbeneficially consumed by riparian vegetation along stream channels. The area of the drainage basin used in this report is about 1,510 square miles, nearly all of which lies in Cassia County, Idaho. A few square miles lie in Oneida and Power Counties, Idaho, and about 270 square miles in Box Elder County, Utah (fig. 1).

Approximately 700 square miles of the area is in the broad, gently sloping Raft River valley that extends southward from the Snake River Plain. Beginning in the 1870's, large tracts of this acreage that could be served by diversion of surface flow from the Raft River and its principal tributaries were developed for agriculture. By the late 1880's nearly all available surface water was appropriated. Pumping ground water for irrigation in the valley started in the 1920's, but it was not until about 1950 that large-scale pumping began for supplemental irrigation and the irrigation of large tracts remote from surface supplies.

Between 1948 and 1952 the quantity of ground water pumped annually for irrigation, as computed from power-consumption records, increased from about 8,700 acre-feet to approximately 22,900 acre-feet. This increased pumping caused local concern that the water resources of the basin were being overdeveloped, and detailed studies were begun by the U.S. Geological Survey in cooperation with the Idaho Department of Reclamation to define and describe the water resources of the basin. These studies resulted in a comprehensive report titled "Water Resources of the Raft River Basin, Idaho-Utah" (Nace and others, 1961).

Ground-water pumping continued to increase until by 1955 the computed pumpage was about 64,000 acre-feet annually. It reached an estimated 112,000 acre-feet in 1960, at which time it was evident that ground-water development had markedly affected the streamflow of the Raft River and was causing water-level declines in the more heavily pumped parts of the valley.

The Geological Survey prepared a report summarizing data collected during the period 1956-60, which documented the effects of pumping for irrigation in the Raft River valley subbasin. The report, "Ground Water in the Raft River Basin, Idaho, with Special Reference to Irrigation Use, 1956-60" (Mundorff and Sisco, 1963), described the magnitude and distribution of water-level declines within the basin and made new estimates of water yield and ground-water underflow from the basin as of 1960.

New and increased use of the ground-water resource continued in the early 1960's with attendant water-level declines. The potential effect of these declines on established water rights caused the State Reclamation Engineer to close the basin in July 1963 to further applications to appropriate ground-water for irrigation. This action was challenged by local interests and litigation followed which pointed up a need for more detailed information on the water resources of the basin and an analysis of the probable effects of continuing the water withdrawals at the 1963 rate.

Consequently, the study upon which this report is based was begun by the Geological Survey in cooperation with the Idaho Department of Reclamation in 1965 and continued through June 1967. The goals of the study were to:

1. Re-describe those aspects of the geologic framework of the basin that influence the occurrence, movement, and availability of the water resource. This re-description to be based on new surface mapping of geologic units, new data from well logs, and the results of regional geologic investigations that led to re-definition of geologic formations and their distribution within the basin.
2. Re-determine the water yield of the basin by independent assessment of precipitation occurrence and distribution, and of natural water loss through evaporation and transpiration.
3. Collect additional records of streamflow on which to base computation of the long-term average annual runoff as an indicator of minimum water yield and changes caused by diversion and use.
4. Update all data related to pumping of ground water, change in water level, distribution of water-bearing units, and use of water for irrigation.

5. Determine a new water budget for the basin which identifies the elements of inflow, outflow, and storage change in terms of current water use as compared with natural basin conditions.

6. Describe the location and magnitude of change in ground-water storage resulting from pumping, and relate the change to total storage available.

CONCLUSIONS

The study provided additional data over that available for earlier investigations and the data, when applied to the enumerated goals, allow interpretations and conclusions that fulfill most of the objectives and current management needs.

1. Ground water suitable for development for irrigation in the Raft River basin occurs in the valley fill--including Holocene alluvium and the Pleistocene Raft Formation--and in the upper part of the Pliocene Salt Lake Formation. Most of this water is in the Raft River valley subbasin, east of the Cotterell Range. There the ground water is generally unconfined, and the several geologic formations constitute a single aquifer with a thickness exceeding 700 feet under most of the lowlands, which is underlain by relatively impermeable rocks. Aquifer permeabilities and yields vary widely from place to place, and are likely to be less in the older formations, whether they are deeply buried under the valley floor or near the surface along the margins of the subbasin. West of the Cotterell Range, the same geologic formations are waterbearing in the Yost-Almo and Elba subbasins, but data are inadequate to delineate aquifer characteristics or thickness. From these subbasins, there is outflow to the Raft River valley subbasin through the alluvial valleys occupied by Raft River and Cassia Creek as they traverse the Cotterell Range.

The Raft River valley subbasin is bordered on the north by basalt which on the grand scale of the Snake River Plain is highly permeable, but which includes massive impermeable rocks as well as very permeable zones. Outflow of ground water from the subbasin through this basalt and included sediments is indicated by a northward water-table gradient of about 15 feet per mile. This underflow occurs along a section about 10 miles wide, but data are still lacking as to the permeability and thickness of the section, so that the rate of underflow cannot be calculated directly.

2. The perennial water yield of the basin is the average natural annual discharge from the Raft River basin. In this, as in previous studies, the yield has been determined indirectly as the difference between the average annual precipitation and the average annual evapotranspiration throughout the Raft River basin under natural conditions. The calculated volume of annual precipitation--1,280,000 acre-feet--is practically identical with the average volume estimated by Nace and others (1961), who also estimated that 86 percent of this volume was returned to the atmosphere by evapotranspiration within the basin, and the remainder of 184,000 acre-feet constituted the water yield. In the present study, the water yield at selected sites was determined by empirical procedures that provide estimates of average monthly precipitation and potential evapotranspiration and soil-moisture deficit at each site; these data were then plotted on a map that was used for computation of average water yield in each subbasin. By this method, the calculated water yield is 140,000 acre-feet and thus 89 percent of the precipitation is lost naturally from within the basin by evapotranspiration. Either calculation of the water yield should be viewed as only a rough approximation, in view of the assumptions and empirical procedures that are involved in estimating evapotranspiration.

3. The natural surface outflow from the Raft River basin, based on measurements of the Raft River as early as 1910, is estimated to have averaged about 17,000 acre-feet a year. The quantity available for man's development and use in the Raft River valley subbasin (east of the Cotterell Range) was considerably greater, for it included average annual inflow of about 18,000 acre-feet from Cassia Creek, 24,000 acre-feet from Raft River at The Narrows, 8,400 acre-feet from creeks draining the Raft River Mountains, and 5,400 acre-feet from creeks rising in the Sublett Range--an aggregate surface inflow of about 56,000 acre-feet. Most of this water contributed to recharge of the ground-water reservoir, or was consumed by riparian or phreatophytic vegetation.

Diversion and use for irrigation of the waters in the mountain creeks has caused progressive reduction in the surface-water inflow to the Raft River in the Raft River valley subbasin. In the 30 years 1931-60, the average inflow has been 12,500 acre-feet from Cassia Creek, 11,600 acre-feet in Raft River at The Narrows, and none from small creeks draining the Sublett and Raft River Mountains. Much of this inflow disappeared by diversion or seepage, so that the river was dry along several miles of its course each year; the outflow was probably between 9,000 and 7,000 acre-feet a

year. By 1967 the inflow in Raft River at The Narrows had dwindled to 6,500 acre-feet, and the spring-fed outflow to less than 2,000 acre-feet. The consumptive use of surface water, estimated at about 40,000 acre-feet a year by riparian vegetation aboriginally, increased to nearly 50,000 acre-feet as the water was applied for irrigation and native vegetation was cleared. Since 1948 the consumptive use of surface water has dwindled with decreasing availability, to about 20,000 acre-feet in the dry year 1966.

4. Pumpage for irrigation from wells in the Raft River valley subbasin began after World War II, increased from 8,600 acre-feet in 1948 to 148,000 acre-feet in 1965, and to 225,000 acre-feet in the dry year 1966. Aggregate pumpage in this subbasin in two decades is estimated to have been about 1½ million acre-feet by the end of 1966. Pumping began in the Yost-Almo subbasin in 1956 and increased to about 8,400 acre-feet in 1966, and in the same year less than 1,000 acre-feet was pumped in the Elba subbasin; the aggregate pumpage in both these subbasins was only 46,000 acre-feet by the end of 1966. Assuming that 40 percent of the water pumped is used nonconsumptively and then returns to the ground-water reservoir, the net withdrawal of ground water for consumptive use throughout the Raft River basin increased from about 5,000 acre-feet in 1948 to 90,000 in 1965 and to 140,000 acre-feet in 1966.

In the Raft River valley subbasin, water levels in wells have been lowered substantially throughout the area irrigated from wells. From the spring of 1952 to 1966, the water table declined under an area of 235 square miles, and the decline exceeded 50 feet in several parts of the valley north of Malta. The volume of materials dewatered during the 14-year period is computed to be about 2 million acre-feet. On the basis of well logs and other data, the average specific yield of the dewatered materials is estimated to be 20 percent, and the water drained from them is thus about 400,000 acre-feet. The water pumped from wells during the period was more than 1,200,000 acre-feet, and assuming that 40 percent of this returned to the reservoir, the net withdrawal was about 740,000 acre-feet. From these data, it would appear that there was inflow to the pumping depression amounting to about 340,000 acre-feet, or an average of about 24,000 acre-feet a year; this may have included lateral inflow, seepage of surface water, and infiltration of precipitation. During the dry year 1966, the gross irrigation pumpage in the subbasin was 225,000 acre-feet. Assuming the same proportionate distribution, 90,000 acre-feet of this was used nonconsumptively and then seeped back to the aquifer; 75,000

acre-feet was removed from accumulated storage; and 60,000 acre-feet was replenished either by infiltration of precipitation or surface water or by lateral inflow to the pumping area.

The water that is pumped for irrigation and then seeps back to the aquifer is likely to carry dissolved salts from the soil and land surface. Several wells in the bottomlands yield water with more than 600 mg/l (milligrams per liter) of dissolved solids, and in some the dissolved solids are chiefly sodium and chloride. These dissolved salts accumulate during natural evapotranspiration of the river water, and available data do not show whether the concentration has been increased by irrigation return. The surface outflow from the valley, however, now has dissolved solids about 30 percent greater than those measured prior to irrigation development.

5. It has been calculated that the average water yield of the entire Raft River basin is about 140,000 acre-feet a year, of which under natural conditions 40,000 acre-feet was consumed by riparian vegetation, 17,000 was surface-water outflow and 83,000 acre-feet ground-water outflow. So far as the main valley--the Raft River valley subbasin--is concerned, most of the natural surface-water inflow of 56,000 acre-feet has been preempted by diversion and use for irrigation in the tributary subbasins, so that by 1967 the surface inflow to the valley subbasin had been reduced to less than 20,000 acre-feet. The total water used for irrigation in the tributary subbasins is greater than the amount of depletion of streamflow to the main valley: Some irrigation consumptive use replaces natural riparian consumptive use, and the water used nonconsumptively for irrigation becomes ground water that may eventually return to the stream or continue by underflow to reach the valley subbasin.

Within the Raft River valley subbasin, the use of water for irrigation doubtless substitutes in part for consumptive use by native riparian vegetation, but the surface outflow has also been reduced from 17,000 to 2,000 acre-feet. The principal consumptive use of water in the valley subbasin, however, is by irrigation with water pumped from wells. In 1966 this consumptive use amounted to an estimated 135,000 acre-feet, approximately equivalent to the calculated water yield from the entire basin.

6. The water pumped from wells for irrigation in 1966 came partly from accumulated storage within the aquifer, and this has been true in every year since pumping began, as shown by the progressive decline of water levels in the areas

of pumping. Whatever the amount of ground-water outflow northward from the basin, pumping has caused no significant change in that outflow, for water levels in the northern outflow area have changed very little during 14 years of progressively increasing pumping. Lowering the water level by 50 feet in an area of intensive pumping has lowered the water table less than 1 foot 4 miles to the north. Basalt in the outflow section has a thickness of several hundred feet--wells have been drilled in it to depths of nearly 500 feet--and a reduction of less than a foot in saturated thickness would cause a very small reduction in the outflow. Until the pumping in the valley has significant effect upon the outflow, accurate determination of the amount of outflow is of academic interest only.

The water pumped from storage comes from the valley aquifer where it is generally most permeable, most productive, and thickest. In the area of most intensive pumping north of Malta, the aquifer extends to depths greater than 1,400 feet, and it is more than 700 feet thick under practically the entire area of irrigation pumping. In this pumping area, the aquifer has an estimated average specific yield of 20 percent--comparable to the materials already dewatered--down to depths generally more than a hundred feet below the water table as of 1967. The older sediments at greater depths and around the margins of the valley have lower permeability and lesser yields, estimated to average about 15 percent. In the Raft River valley subbasin, it is estimated that the permeable sediments down to depths 200 feet below the water table in 1967 contain 9,000,000 acre-feet of water in storage.

7. All studies, including this one, have noted the quantity of ground water leaving the Raft River valley subbasin as ground-water outflow. This water, once it moves northward into the Snake River Plain, is lost to use within the Raft River basin. Thus, many have been led to believe that pumping near the outflow area would intercept a major part of the water now moving from the basin as underflow. The pumping to date, however, has not reduced the outflow by any significant amount. Although pumping until 1966 was less than the calculated perennial yield of the basin, much of that "yield" continued to flow out of the basin; the pumping was in excess of local replenishment and, therefore, in part from accumulated storage in the aquifer. Continued pumping can be expected to broaden and deepen the existing cones of depression, and to cause further depletion of storage and increased pumping lifts before any significant decrease in subsurface outflow occurs.

This depletion of ground-water storage poses many problems to the development and use of the ground-water resource. Of particular importance is the realization that the ground-water resources have been and are being depleted, and that this depletion may continue for decades under present pumping practices. The depletion will continue during a transient state of imbalance that began when man first disturbed the natural equilibrium, and will end only when a new equilibrium is reached, with the perennial yield diverted and used by man. In the course of this depletion, it must be anticipated that so long as present pumping practices continue there will be a progressive increase in pumping lifts and decreases in well yields. The information on which to base an estimate of the point in time at which a new equilibrium would be established is not now available.

PREVIOUS WORK AND REPORTS

The general geology and water resources of the Raft River basin have been studied in part and in varying detail by several workers. Despite this work, the geology of the valley areas and the regional structural features are still imperfectly known, and more detailed investigations and further data collection are needed on which to base detailed hydrologic analysis of the basin. The results of all previous work in the basin have been used in the analyses, interpretations, and conclusions of this report.

The earliest known study of the hydrologic characteristics of the area was made by Stearns and others in 1928 during a reconnaissance of the Snake River Plain and tributary valleys. This work was published in two reports (Stearns and others, 1936, 1938). Kirkham (1931) compared the Tertiary stratigraphy of the Raft River basin with that of other areas in southern Idaho. The basic reference on the geology of the area was prepared by Anderson (1931), who described the general geology and mineral resources of eastern Cassia County with special emphasis on the upland areas. The report contributed little information about the geology of the valley lowlands.

Fader (1951) prepared a preliminary report which contained records of wells, ground-water levels, and pumpage for irrigation. The most comprehensive report of the water resources of the basin, however, including well data and estimates of all elements of the hydrologic budget, was prepared

by Nace and others (1961) as the result of work done in 1948-55. That report discussed estimates of the total water yield of the basin, the amounts of that yield available as surface water and as ground water, the amount of ground water that might be recovered for beneficial use, and the effects of such use on downstream water supplies. However, the accuracy of the estimates was greatly limited by the sparse records then available.

A report by Crosthwaite and Scott (1956) contained data on wells at the extreme northern end of the basin, and Felix (1956) presented data on the geology of the eastern part of the Raft River Mountains. Mundorff and Sisco (1963) completed a brief study of the valley part of the area in 1960 and published a short report containing water levels, declines of water level since 1952, pumpage, and estimates of water yield and ground-water outflow. A principal conclusion of the report was that ground-water development during 1955-60 had materially reduced the unused and uncommitted underflow from the basin and that continued ground-water pumping could economically intercept perhaps one-fourth of the then estimated 140,000 to 200,000 acre-feet leaving the basin as underflow. An unpublished report by Haight (1965) contained data on pumpage of ground water through 1964, water levels as of the spring of 1965, and water-level change.

Additional information about the geology of the mountainous parts of the area was published by Armstrong (1966), Compton (1966), and Damon (1966). The Utah part of the basin was described on a reconnaissance geologic map (Butler and others, 1920, pl. 4), but the work was too general to be useful in this study.

Present use of water in the basin is considered in the report only in relation to the hydrologic system. The analysis is directed toward the storage and movement of water in the system. The merits, effectiveness, or relative efficiency of the various uses are considered to be beyond the scope of this report. The report is intended principally for use by persons who have the responsibility of managing the basin and for selecting alternative plans of developing or regulating the water resources of the valley.